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RESEARCH PAPER

Allelopathic effects of leaf litters of *Eucalyptus camaldulensis* on some forest and agricultural crops

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Abstract: Allelopathic effects of different doses of *Eucalyptus camaldulensis* leaf litters were investigated through an experiment in the green house of Institute of Forestry and Environmental Sciences, Chittagong, Bangladesh. Three popular agricultural crops: Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*), Arhor (*Cajanus cajan*) and two widely used plantation trees: Sada koroi (*Albizia procera*) and Ipil ipil (*Leucaena leucocephala*) were selected as bioassay species. Experiment was set on tray at room temperature 27°C. The effects of different doses of leaf litter extracts were compared to the control. Results suggest that leaf litters of *E. camaldulesis* induced inhibitory effects. It was also found that the effect depend on concentration of extract and litterfall, type of receiver species. Higher concentration of the materials had the higher effect and vice versa. Though all the bioassay species were suppressed some of them showed better performance. *Vigna unguiculata*, *Cicer arietinum* are recommended in agroforestry based on this present Experiment output. In mixed plantation, *Leucaena leucochephala* is a better choice while compared to *Albizia procera*.

Keywords: agroforestry; choice of species; inhibitory effect; leaf litters; mixed cropping; mixed plantation

Introduction

In Bangladesh several tree species are grown in or around the agricultural crop fields as the traditional agroforestry system, even then the country is experiencing a shortage of fuel wood and fodder for domestic uses (Huq and Alim 1995). Presently, over 100 Non Government Organizations (NGOs) are engaged in rural development activities, which include nursery raising and tree planting programme all over the country. Participatory forestry initiatives by the Forest Department and the NGOs include roadside tree plantations, homestead tree planting programme etc (Huq and Alim 1995). Total plantation areas proposed in the current 20 years Forestry Master Plan are 164,500 ha under participatory plantation programme and 398 300 ha under industrial and environmental programme at a moderate level of development (Huq and Alim 1995). It is expected that the future plantation will increase yield per unite land by replacing bare, low quality, sparse or degraded areas, on one hand, and increase yield of commercial products on the other. Under integrated land use system a tree crop and a food crop may be grown on the same piece of land with a proper combination of both the tree and agricultural crops (Bene et al. 1977). An increased productivity in the future plantations both on forest lands and rural areas can only be achieved by planting tree species and agri-crops in a combination which can imply a promotory rather than inhibitory tree crop interaction. Reduction in yield of agri-crops and or poorer growth of tree seedlings is often blamed on mismatching of crop combinations. Part of the problems, in fact, lies in the selection of tree and food crop combination, and inhibitory effects of some leaf leachates on adjacent agricultural crops. King (1979) pointed out the need for investigations of allelopathy in various tree species used in agroforestry where there is a good chance of allelochemicals released by the intercrop trees affecting food and fodder crops. Therefore, it seems essential that the allelopathic compatibility of crops with trees should be checked before introducing in agroforestry system (Khan and Alam 1996). *Eucalyptus camaldulensis* has been planted in degraded areas as well as in the agroforestry programmes for the uplift of socio-economic condition of the rural people for a long time. Davidson and Das (1985) reported that *E. camaldulensis* proved superior in production of yield and biomass, but recent embargo on *Eucalyptus* plantation in Bangladesh is the outcome of media rather

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than on the basis of experimental results. There have been a number of studies on allelopathy in *Eucalyptus*, particularly in India where planting of *Eucalyptus* is greatly controversial (Willis 1991). Recently Luo (2005) stated that less vegetation exists under *Eucalyptus* canopy than local trees. Recent study by Lin et al. (2003) showed that water, ethanol, or acetone extracts from *Eucalyptus urophylla* also have allelopathic effect on *Pisolithus tinctorius*, a common fungus in South China. Though many works are being done all over the world on allelopathy, it is still very new in Bangladesh (Uddin et al. 2000; Hossain et al. 2002; Hoque et al. 2003[a,b,c,d]). So, the purpose of the present study is to elucidate the allelopathic potential of Eucalyptus on some common agriculture and forest crops.

Materials and Methods

The experiment was set in the green house of Institute of Forestry and Environmental Sciences, Chittagong University. Soils were collected from the barren hills of Chittagong University campus. Leaf litters were collected from the 8-year-old *Eucalyptus camaldulensis* plantation of same campus. Three popular agricultural crops: Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*) Arhor (*Cajanus cajan*) and two widely used plantation trees: Sada koroi (*Albizia procera*) and Ipil ipil (*Leucaena leucocephala*) were selected as bioassay species. Inner portion of the trays (22.86 cm x 22.86 cm) were wrapped with soft cloths and then filled with treated soil according to the following treatments:

T_0= Seeds of receptor plants with barren hill soil only,
T_1= Seeds of receptor plants mixed with litter of 1.046 gm/tray,
T_2= Seeds of receptor plants mixed with litter of 5.22 gm/tray,
T_3 = Seeds of receptor plants mixed with litter of 10.46 gm/tray
T_4= Seeds of receptor plants mixed with litter of 15.6 gm/tray and
T_5= Seeds of receptor plants mixed with litter of 20.96 gm/tray.

Germination of the crops was regularly recorded up to the notice of last germination. Watering and weeding was regularly done. The agricultural crops were harvested after one and half month and forest crops after two and half months. The effect was compared with control treatments. The data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT).

Ratio of germination and elongation were calculated as suggested by Rho and Kil (1986):

$$RGR=\frac{GR_t}{GR_c}\times 100 \quad (1)$$

where, RGR is the relative germination ration, GR_t the germination ratio of tested plant, and GR_c is the germination ratio of control

$$RER=\frac{ML_t}{ML_c}\times 100 \quad (2)$$

where, RER is the relative elongation ratioof shoot, ML_t the mean lenth of shoot of tested plant, and MLc is the mean length of control.

For the calculation of percentage of inhibitory effect on the radicle and plumule elongation, percentage to the control was calculated as per formula evolved by Surendra and Pota (1978):

$$I=100-(E_2\times 100/E_1) \quad (3)$$

where, I is the % inhibition, E_1 the Radicle and plumule elongation of control plant and E_2 the Radicle and plumule elongation of treatment plant.

Results

Germination

Germination of different seeds of test crops showed significant variation in different treatments. Usually with the increased application of leaf litter percentage, germination rate of crops reduced (Table 1). Response of germination percentage at T_1 treatment was higher than that of control in case of all crops except *V. ungiuculata*, which was found to be highest (100%) at T_4 treatment. Highest (112.35%) Relative Germination Ratio (RGR) was found in *V. ungiuculata* at T_4 treatment while lowest (74.49%) was found in *A. procera* at T_5 treatment. Among the test crops *V. ungiuculata* was found to response positively in all treatments (Fig. 1).

Table 1. Germination (%) of different receptor crops to the application of different ratio of *E. camaldulensis* leaf litters in tray

Treatments	Agricultural/ Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	98 b	93 d	89 b	98 b	96 b
T_1	100 a	96 c	91 d	100 a	100 a
T_2	96 c	100 a	93 c	100 a	100 a
T_3	87 d	97b c	98 b	95 c	100 a
T_4	98 b	98 b	100 a	94 c	82 c
T_5	96 c	71 e	98 b	73 d	78 d

*Values followed by the same letter(s) are not significantly different (P≤ 0.05) according to DMRT.

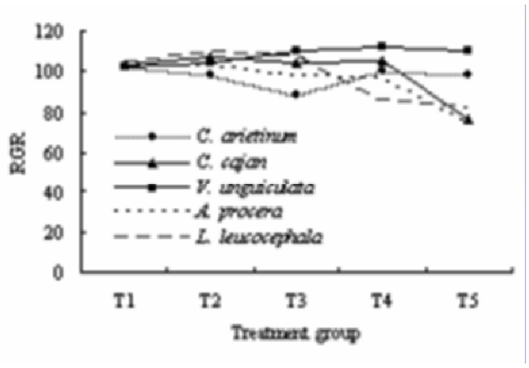

Fig. 1 Relative Germination Ratio (RGR) of test plants on different proportion of *E. camaldulensis* leaf litter

Shoot growth

The effects of *E. camaldulensis* litter on the growth of tested seedlings showed that the shoot length of all the crops was shorter than that of the control in all treatments except *C. arietinum* at T_1 treatment (Table 2). It stimulated 7.19% shoot growth of the crop. The results also revealed that the effect was increased with the increased percentage of leaf litter application. However, the effect was not evenly increased. Some cases T_5 treatment had less effect than T_4 treatment. Between forest and agricultural test crops, forest crops were affected severely than that of agricultural crops. For example, highest reduction of *A. procera* and *L. leucocephala* was 37.90% and 35.89% respectively while highest reduction of agricultural crops of *C. cajan, V. unguiculata* and *C. arietinum* was 15.65% 11.79% and 8.42% respectively. Relative Elongation Ratio (RER) was highest (100.5%) in *C. arietinum* at T_1 treatment and lowest (62.1%) in *L. leucocephala* at T_3 treatment (Fig. 2).

Table 2. Shoot length (cm) of different receptor crops to the application of different ratio of *E. camaldulensis* leaf litters in tray.

Treatments	Agricultural/ Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	29.92 ab	27.21a	22.3 a	22.33 a	32.88 a
T_1	32.07 a (+7.2)	25.71b (-5.5)	21.25 ab (-4.7)	21.00 ab (-5.9)	32.25 a (-1.9)
T_2	29.33 b (-1.9)	24.11c (-11.4)	20.36 b (-7.2)	17.83 abc (-20.15)	20.75 b (-36.9)
T_3	28.43 b (-4.9)	23.00c (-15.4)	19.5 c (-12.4)	19.67 ab (-11.9)	20.42 b (-37.9)
T_4	28.46 b (-4.8)	23.95c (-12)	20.09 c (-9.9)	16.17 bc (-27.6)	22.00 b (-33.0)
T_5	27.4 b (-8.4)	22.95c (-15.6)	19.67 c (-11.8)	14.17 c (-36.5)	21.08 b (-35.9)

*Values followed by the same letter(s) are not significantly different (P≤ 0.05) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (To).

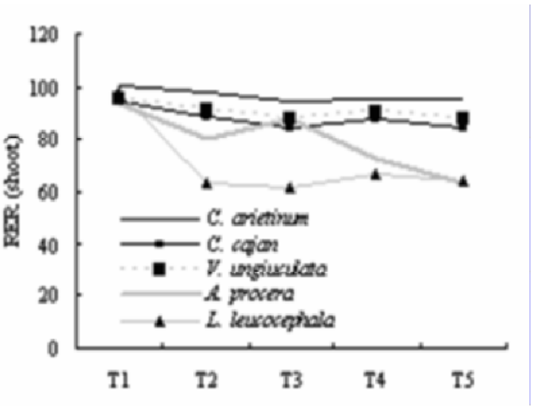

Fig. 2 Relative Elongation Ratio of shoot of seedlings grown in tray filled with different proportion of *E. camaldulensis* leaf litter

Root growth

The effects of *E. camaldulensis* leaf litter on the growth of tested seedlings showed that the root length of the crops was differently responded to different treatments. Both stimulatory and inhibitory effects were observed. However, the effect was unevenly increased with the increase of percentage of leaf litter application. *C. arietinum* had the shorter root length in all treatments in comparison to control. On the contrary *C. cajan* was found to be stimulated with the increase of litter application. Highest inhibitory effect (21.81%) was found in *L. leucocephala* at T_5 treatment and lowest (2.80%) was found in, *V. unguiculata* at T_3 treatment. While highest stimulatory effect (16.73%) was found in *C. cajan* at T_5 treatment and lowest (0.12%) in the same crop at T_4 treatment (Table 3).

Table 3. Root length (cm) of different receptor crops to the application of different ratio of E. camaldulensis leaf litters in tray

Treatments	Agricultural / Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A procera*	*L. leucocephala*
T_0	3.8 a	8.4 9b	9.27 ab	*10.5 a*	*12.92 ab*
T_1	3.37 bcd (-11.3)	8.9 ab (+4.8)	9.6 a (+3.7)	9.5 ab (-9.5)	14.5 a (+12.23)
T_2	3.6 ab (-5.3)	8.25 b (-2.83)	9.47a (+2.2)	9.07 ab (-13.6)	12.33 ab (-5.47)
T_3	3.3 cd (-13.1)	8.95 ab (+5.4)	9.01abc (-+2.8)	10.92 a (+4.0)	12.08 ab (-6.5)
T_4	3.25 d (-14.5)	8.59 b (+0.1)	8.54 bc (-8.3)	9.28 ab (-11.6)	12.08 ab (-6.5)
T_5	3.57 abc (-6.0)	9.91 a (+16.7)	8.33 c (-10.1)	8.21 b (-21.8)	11.33 b (-12.31)

*Values followed by the same letter(s) are not significantly different (P≤ 0.05) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (To).

Collar dia (mm)

Statistically significant variation of collar diameter was observed among different treatments for all the crops (Table 4). Control had higher collar diameter in all crops except *A. procera*. T_1 treatment was found to be stimulated the collar diameter of *A. procera*. Increasing reduction trend was observed from treatment T_1 to onwards. Reduction of collar diameter was highest (32.28%) in *L. leucocephala* followed by the same crop at T_5 and T_4 treatments respectively and lowest reduction (2.5%) was recorded from *A. procera* at T_3 treatment.

Root diameter

Average expansion of secondary roots of test crops was measured and express as root diameter. Significant hindrance of root diameter was found in all most all concentrated extracts. However effect varied from treatment to treatment as well as from

crop to crop. For example *A. procera* had root diameter with no significant differences among the treatments though it gradually decreased from lower to higher percentage of leaf litter application. In all other cases significant hindrance was observed in increasing trend at higher percentage of leaf litter. Highest reduction was (42.0%) found in *L. leucocephala* at T_4 treatment while lowest was (2.0%) in *C. cajan* at T_5 treatment (Table 5).

Table 4. Collar dia (mm) of different receptor crops to the application of different ratio of *E. camaldulensis* leaf litters in tray

Treat ments	Agricultural/ Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	2.22ab	1.84 a	3.01a	2.03ab	3.28a
T_1	2.1 ab	1.64 b	2.71 b	2.15 a	3.03 a
	(-5.4)	(-10.8)	(-9.9)	(+5.9)	(-7.6)
T_2	1.94 bc	1.48 c	2.53 bc	1.94 ab	2.19 b
	(-12.6)	(-19.6)	(-15.9)	(-4.4)	(-33.2)
T_3	1.82 c	1.44 c	2.45 c	1.98 ab	2.38 b
	(-18.0)	(-21.7)	(-18.6)	(-2.5)	(-27.4)
T_4	1.72 c	1.45 c	2.53 bc	1.73 b	2.12 b
	(-22.5)	(-21.2)	(-15.9)	(-14.8)	(-35.4)
T_5	1.75 c	1.4 c	2.6 bc	1.69 b	2.09 b
	(-21.2)	(-21.1)	(-13.6)	(-16.7)	(-36.3)

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT. Value in the parenthesis indicates the stimulatory (+) or inhibitory (-) effects in comparison to control (To).

Table 5. Root dia (cm) of different receptor crops on the application of different ratio of *E. camaldulensis* leaf litters in tray

Treat ments	Agricultural / Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	3.8 a	3.5 a	3.89 a	4.0 a	6.33 a
T_1	3.37 bcd	3.49 a	3.48 b	3.91 a	5.33 ab
T_2	3.6 ab	3.14 b	3.42 b	3.83 a	4.17 bc
T_3	3.3 cd	3.12 b	3.25 b	3.67 a	4.33 bc
T_4	3.25 d	3.41 ab	3.42 b	3.58 a	3.67 c
T_5	3.57 abc	3.43 ab	3.31 b	3.43 a	4.0 c

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT.

Leaf Number

Table 6 shows the leaf number of tested forest and agricultural crops in response to the application of different percentage/dose of *E. camaldulensis* leaf litter in tray. The results revealed that leaf number of test seedlings of *C. arietinum* following treatments was fairly uniform with no significant difference among the treatments and the control. However, leaf number in other cases significantly reduced and it was decreased when application of leaf litter increased. T_1 treatments stimulated the leaf number of *V. unguiculata* and *A. procera* as 4.78% and 18.28% respectively. Highest reduction (30.27%) was found in *L. leucocephala* at T_5 treatment while lowest (1.41%) was in *C. arietinum* at T_1 treatment (Table 6).

Table 6. Leaf no. of different receptor crops on the application of different ratio of *E. camaldulensis* leaf litters in tray

Treat ments	Agricultural / Forest crops				
	C. arietinum	*C. cajan*	*V. unguiculata*	*A. procera*	*L. leucocephala*
T_0	19.15 a	5.33 a	2.93 a	7.33 bc	11.0 a
T_1	18.87 a	4.27 b	3.07 a	8.67 a	10.67 a
T_2	18.07 a	4.0b c	2.27 b	7.33 bc	8.17 b
T_3	16.07 a	3.8 c	2.13 b	8.5 ab	8.17 b
T_4	17.53 a	3.6 c	2.4 b	7.0 c	8.67 b
T_5	16.07 a	3.73 c	2.27 b	7.0 c	7.67 b

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT.

Nodule Number

The study revealed that leaf litter of *E. camaldulensis* had inhibitory effect on nodulation of test plants. The trend of effect was increasing with the increasing of leaf litter. However, different test plants responded differently in different treatments. *V. unguiculata* and *C. cajan* had the higher number of nodule in Control and then a significant decreasing trend was found from treatment T_1 to onwards. *A. procera* was the exception on which stimulating effect on nodulation was observed up to treatment T_4 though a remarkable reduction in number was recorded at T_5 treatment. Highest reduction was (76.39%) found in *A. procera* at T_5 treatment while lowest (5.5%) was in *C. cajan* at T_1 treatment (Table 7).

Table 7. Nodule No. of different receptor crops on the application of different ratio of *E. camaldulensis* leaf litters in tray

Treatments	Agricultural crops		
	A procera	*C. cajan*	*V. unguiculata*
T_0	20.33 b	9.6 a	9.87 a
T_1	31.50 ab	9.07 ab	7.87 ab
T_2	37.17 a	8.27 ab	7.33 bc
T_3	24.33 b	8.07 ab	7.27 bc
T_4	22.33 b	8.78 ab	6.73 bc
T_5	4.86 c	7.27 b	5.53 c

*Values followed by the same letter(s) are not significantly different ($P \leq 0.05$) according to DMRT.

Nodule size

Size of three largest nodule of *A. procera* and *L. leucocephala* in each replicated treatments was measured and the average size is shown in Fig. 3. The result shows that the size was significantly reduced in comparison to control and lowest size was found at T_5 treatment. An opposite relation of number and size was found incase of *A. procera* as it size affected adversely from treatment T_1 while its nodule number was found to increase up to T_4 treatment. Both the average smallest and largest size of the nodule were found in *A. procera* at T_5 and T_0 treatment respectively

Leaflet

V. unguiculata and *C. cajan* was found to have leaflet and they were counted. The fate of leaflet number of the crops in different treatments was similar as was found in case of leaf number and other growth parameters. For both crops maximum number was found at control and minimum was found at T5 treatment for V. unguiculata and T4 treatment for *C. cajan* (Fig. 4).

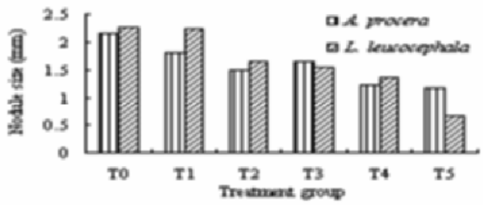

Fig. 3 Nodule size (mm) of different receptor crops on the application of different ratio of *E camaldulensis* leaf litter in tray

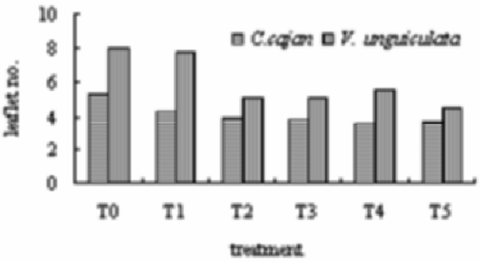

Fig. 4 Leaflet of different receptor crops on the application of different ratio of E. camaldulensis in tray

Discussion

The foregoing results clearly indicate the suppressive effect of Eucalyptus camaldulensis, on germination, shoot and root elongation, nodulation, root diameter and development of lateral root of bioassay species. Several researchers such as Bowman and Kirkaptric (1986), Igboanugo (1986, 1987), Lovett (1989) have also reported the similar effect of *Eucalyptus* species. Hillis and Brown (1988) pointed out that various *Eucalyptus* species could yield allelopathic chemicals that may be effective in suppressing under-storey vegetation. All species of *Eucalyptus* have foliar oil glands that are rich in essential oils, principally terpeneoids; typically 1 to 5 percent of the fresh weight is essential oils (Barker and Smith 1920; Guenther 1950). The leaves contain diverse phenolic compounds (Hillis 1967; Hillis and Brown 1988). It has long been recognized that many eucalypt extracts have strong antibiotic properties (Bowman and Kirkaptric, 1986). Swami Rao and Reddy (1984) also found the inhibitory effect of *Eucalyptus* (hybrid) leaf extracts on germination of certain food crops. May and Ash (1990) pointed out that various *Eucalyptus* species could yield allelopathic chemicals that may be effective in suppressing under-story vegetation. Furthermore, May and Ash (1990) used technique resembling more ecological processes, that is, extraction mimicked natural rainfall rates, root leachates, stemflow, soil leachates and volatiles from leaves. Kohli *et al.*, (1990) reported that Rabi and Kharif crops showed poor performance in terms of density, biomass, root and shoot length and economic yield in comparison to unsheltered areas. Singh and Kohli (1992) have studied the impact of *Eucalyptus tereticornis* shelterbelts on some crops in India. They concluded that the poor performance of crops in the *Eucalyptus* shelterbelts area was related to an allelopathic effect of *Eucalyptus*. Costing (1954) reported that the peppermints, *Eucalyptus dives* and *E. radiata* of the Monaro region in New South Wales may exert an analogous influence on surrounding vegetation. It has often been reported that there is a ring of sparse vegetation beneath single eucalypt trees, which is particularly obvious in aerial photographs. Story (1967) suggested that such vegetational patterning beneath *Eucalyptus crebra, E. dawsonii, E. melliodora* and *E. moluccana* in the Hunter Valley region of New South Wales was not explainable by grazing or differences in soil moisture, and was possibly due to the action of associated microorganisms or exudates. Similar observations were made by Lange and Reynolds (1981) who reported the selective suppression of the herb *Gonocarpus eletius* beneath canopies of *Eucalyptus microcarpa*. Cremer (1990) reports that *E. camaldulensis* may exert a negative effect on the grazing yield of pasture in Western Australia. The presence of terpenes in eucalypt soils also has been reported by del Moral et al. (1978) and Lovett (1985). Many soils are water repellent, although this phenomenon is generally believed to be linked to fungal activity (Hubble *et al.*, 1983). Prescott (1941) concluded that the usual paucity seed germination is a reflection of harsh conditions and that germination occurs readily under favorable conditions.

Conclusion

Eucalyptus of all genuses dominates the world's forests and woodlands, none dominate regionally to the extent that *Eucalyptus* does, and allelopathy offers a ready explanation of eucalyptus dominance (van Steenis 1971). Few genera would have a better chemical armory than *Eucalyptus*. Eucalyptus as an agroforestry component tree has been used for a long time. Recently a controversy among the planters has been arisen due adverse effect to the adjoining crops, much of it came from neighboring countries (Dhillon et al. 1982; Kohli et al. 1990). Other controversies linked with the tree include lowering of water table, depletion of nutrients due to lesser leaf production in comparison to bole, delayed decomposition due to presence of volatile oils and waxy coating in the leaves and more soil sap requirement to meet the demands of fast growing and dividing cells (Kohli 1991). Keeping aside such controversies linked with the tree, the area under eucalyptus plantation often houses poor vegetation. It is alleged that in spite of sufficient light intensity, nutrients or space to support vegetation, there is low biodiversity on its floor, for such an antiphytosocial property, allelopathy has been proposed to be the reason (Kohli 1990). Present study results reveal that on *Ca-*

janus cajan suppressive effects are higher compared to other agricultural crops used here. We would like to suggest that Eucalyptus would cause yield loss of several crops in mixed cropping pattern but it would wise to plant Falen (*Vigna unguiculata*), Chickpea (*Cicer arietinum*) in agroforestry based on this present Experiment output. More over in mixed plantation *Leucaena leucochephala* would be a better choice while compared to *Albizia procera*.

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